S-5B Edition 1.0.1

Standards of Competence for Category "B" Hydrographic Surveyors

IHO

International Hydrographic Organization

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Contents

Foreword

Comments arising from the experience gained in the application of the standards are welcome. They should be addressed to the Chair of the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers at the above address. This document is published periodically. Please check with IHO for the latest edition, including current amendments.

Introduction

All components of the hydrographic surveying and nautical cartography professions face challenges as how best to ensure the continuance of high standards and how best to ensure the continuation of best practices based on minimum standards of competence world-wide. In order to achieve these objectives, three international organizations (FIG, IHO and ICA) have developed Standards of competence that institutions or professional bodies may adopt for their educational/training programmes and competency schemes.

Standards indicate the minimum competences considered necessary for hydrographic surveyors.

Standards recognize two levels of programme. Category A programmes introduces content and learning outcomes primarily from the underlying principles level. Category B programmes introduce them primarily from a practical level.

The intention is that a Category A qualified individual with appropriate experience, would be a senior professional in their chosen field (government, industry, academia). Category B qualified individuals with appropriate experience would be technical professionals preparing and delivering products and services to meet specifications and outcomes.

Terms and definitions

Subjects, topics, and elements

The S5-B standard contains the following list of ***B****asic subjects* and ***E****ssential subjects:*

B1: Mathematics, Statistics, Theory of Errors

B2: Information and Communication Technology

B3: Physics

B4: Earth Sciences

B5: Nautical science

B6: Meteorology

E1: Underwater Acoustics

E2: Remote Sensing

E3: Water Levels and Flow

E4: Positioning

E5: Hydrographic Practice

E6: Hydrographic Data Management

E7: Environment

CFFP: COMPREHENSIVE FINAL FIELD PROJECT

Topics and Elements:

— Each **Essential** or **Basic** *subject* is comprised of a list of *topics* which are denoted by Ex.y or Bx.y;

— Each *topic* contains *elements* which aredenoted by Ex.y<c>.

For example, the *subject* E5 “Hydrographic practice” contains the *topic* E5.1 “Hydrographic survey projects” which has the *element* E5.1a “Hydrographic surveys purposes”.

Learning outcomes and list of content

It is important to understand that each *element* is associated with:

— an intended *learning outcome*, that a student should be able to achieve on completion of the programme. All *learning outcomes* should be evaluated, either by or through a combination of, assessment, examination, laboratory work or final project work.

— a list of *content*. This list is associated with one or more *learning outcomes* and describes the theoretical knowledge or practical/technical context which the course syllabi should address in order to meet a particular *learning outcome*.

For the sake of clarity, a level of knowledge associated with each learning outcome has been defined. It is indicated in italics in the left column, by a letter (*B: Basic, I: Intermediate;* see “Guidelines for the Implementation of the Standards of Competence for Hydrographic Surveyors”). This letter designation (*B: Basic, I: Intermediate*) complements the learning outcome description associated with each element.

Programme preparation and submission

The preparation of a programme submission to the IBSC should be done in accordance with the document entitled GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS. This document is available from the IHO website: www.iho.int → Standards & Publications.

The cross reference table is a mandatory requirement for a programme submission and **MUST** be completed. A template is specified and is available from the IHO website: www.iho.int

List of acronyms and initialisms used in this document

1D	One-dimensional
2D	Two-dimensional
ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
B	Basic (level of knowledge)
CAD	Computer Aided Design
CFFP	Comprehensive Final Field Project
DGNSS	Differential Global Navigation Satellite System
EPIRB	Emergency Position Indicating Radio Beacon
FIG	International Federation of Surveyors
GIS	Geographical Information System
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GRS80	Geodetic Reference System (1980)
I	Intermediate (level of knowledge)
IBSC	International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers

ICA	International Cartographic Association
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
INS	Inertial Navigation System
LAN	Local Area Network
LiDAR	Light Detection And Ranging
MBES	Multi Beam Echo Sounder
MSL	Mean Sea Level
NAVTEX	Navigational Telex
P	Practicals (fieldwork and/or laboratories)
RAM	Random Access Memory
ROV	Remotely Operated Underwater Vehicle
S-44	IHO Publication S-44 — *Standards for Hydrographic Surveys*
S-100	IHO Publication S-100 *Universal Hydrographic Data Model*
S-102	IHO Publication S-102 *Bathymetric Surface Product Specification*
SARSAT	Search And Rescue Satellite Aided Tracking
SBES	Single Beam Echo Sounder
SDB	Satellite Derived Bathymetry
SDI	Spatial Data Infrastructure
SG	Self-guided exercises (or student's personal independent work)
SSDM	Standard Seabed Data Model
T	Theoretical (theory through lectures)
TIN	Triangulated Irregular Network

UNCLOS	United Nations Convention on the Law of the Sea
USBL	Ultra Short Baseline
UTM	Universal Transverse Mercator
WGS84	World Geodetic System (1984)
XML	Extended Markup Language

Standards of Competence for Category "B" Hydrographic Surveyors

1. Basic subjects

1.1. B1: Mathematics, Statistics, Theory of Errors

Topic/Element	Content	Learning outcomes
B1.1 Linear Algebra *(B)*	a) Vector and affine spaces, vector and inner products, norms. b) Linear equations, determinants. c) Analytical geometry, line and plane equations. d) Linear operators, matrix representation, composition, inverse, transpose. e) Translations, rotations, coordinate transformations.	Describe and apply 2D transformations involved in surveying and mapping. (E4. 1c) Solve linear equations using matrix methods.
B1.2 Differential calculus *(B)*	a) Real and vector valued functions. b) Gradient of real-valued functions and their discrete approximations. c) Series and integrals.	Compute the gradient of a vector valued function. Define a function as a series. Calculate explicit integrals of classical functions.
B1.3 Trigonometry *(B)*	a) Basic trigonometry b) Sphere, great circle, rhumb lines, sphere angles, spherical triangles and spherical excess.	Apply plane and spherical trigonometry to surveying problems.
B1.4 Statistics *(I)*	a) Random variables, mean, variance, standard deviation b) Covariance and correlation c) Estimation of mean, variance, covariance	Explain what is meant by a random variable, estimate the mean, variance and standard deviation for a random variable and also the covariance between random variables.

Topic/Element	Content	Learning outcomes
	d) Normal distribution	
B1.5 Theory of errors *(B)*	a) Linear observation equations b) Covariance propagation law	Apply the variance propagation law to a linear observation equation, and derive a measurement uncertainty as a function of observables' covariances.
B1.6 Least squares *(B)*	a) Least squares procedure b) Covariance of estimated parameters c) Use of unit variance factor estimate d) Interpretation of ellipses of confidence	Interpret results from a least square estimation applied to survey measurements.
B1.7 Interpolation *(B)*	a) 1D polynomial interpolation b) Spatial interpolation by inverse distance weighting methods	Differentiate between 1-D and spatial interpolation methods. Create and compare interpolated surfaces from one set of sparse survey measurements using appropriate software under different configurations.

1.2. B2: Information and Communication Technology

Topic/Element	Content	Learning outcomes
B2.1 Computer systems *(I)*	a) Central Processing Unit b) RAM, data storage c) Communication board, serial links, communication ports buffers, Ethernet links, data transmission rates d) Communication protocols e) Clocks, clocks drift, time tagging and synchronization of data	Describe the different components of a real-time data acquisition system, including various modes of communication and time-tagging. Describe the role of a device driver and its relation to data exchange.

Topic/Element	Content	Learning outcomes
	f) Operating systems g) Device drivers	
B2.2 Office work software suites *(I)*	a) Word processors b) Spreadsheets c) Graphics and image processing software d) Database management systems and query languages	Use classical office work software suites. Construct a database, populate it and query its content.
B2.3 Programming *(I)*	a) Basic operations of a computer program or script b) Algorithms (loops, conditional instructions) c) Scientific computation environments d) Application to data exchange, file conversion	Write a program for data format conversion and/or basic algorithm computation.
B2.4 Web and network communications *(B)*	a) Networks (LANs) b) Internet c) Networks integrity d) Communication protocols	Describe the different network communication protocols used in remote data exchange applications.
B2.5 Databases *(B)*	a) File types (binary, text, XML) b) Relational databases c) Geospatial databases	Describe different types of geospatial data and their representation.

1.3. B3: Physics

Topic/Element	Content	Learning outcomes
B3.1 Mechanics *(B)*	a) Kinematics (angular and linear velocities, accelerations) b) Coriolis Effect c) Newton's law, forces, accelerations, energy	Describe the relationship between linear and rotational motions through acceleration and velocity
B3.2 Gravity *(B)*	a) Gravity field of the earth b) Equipotential surfaces	Describe the gravity field of the earth in terms of acceleration and potential
B3.3 Waves *(B)*	a) Electromagnetic waves b) Pressure waves c) Ocean waves d) Wave Propagation e) Electromagnetic spectrum f) Radiation, emission and absorption g) Reflection, refraction, diffraction	Differentiate between types of waves and their generation and propagation. Explain how medium parameters affect wave behavior.

1.4. B4: Earth Sciences

Topic/Element	Content	Learning outcomes
B4.1 Geography and geology *(B)*	a) Plate tectonics, earthquakes zones b) Different types of rocks c) Erosion and deposition d) Rivers and estuaries	Describe the internal structure, the physical characters and dynamics of the Earth referring to ocean basin structure, and the major processes affecting coastal morphology
B4.2 Substrates *(B)*	a) Sediment types b) Sedimentary cycles	Distinguish common seafloor characteristics. Describe the ocean bottom as a multilayered structure composed of sediment deposits

Topic/Element	Content	Learning outcomes
	c) Siltation d) Submerged aquatic vegetation e) Corals	

1.5. B5: Nautical science

Topic/Element	Content	Learning outcomes
B5.1 Conventional aids to navigation *(B)*	a) Types of buoys and beacons b) Radar beacons c) AIS systems	Describe the principal fixed and floating aids to navigation and the use of automatic identification systems.
B5.2 GMDSS *(B)*	a) Sea areas b) EPIRBs and SARSAT c) Digital selective calling d) NAVTEX e) Inmarsat-C	Describe the components and purpose of GMDSS.
B5.3 Nautical charts *(B)*	a) Content, datum, projection, scale and types of nautical charts b) Chart symbols c) Chart graticules d) Uncertainty indicators (e.g. source diagram, reliability diagram, zone of confidence, notes) e) Navigational hazards f) Plotting instruments	Layout a route on a nautical chart, plot positions, identifies navigational hazards and revise navigational plan as required. Describe the content of a nautical chart and explain datum, projection, scale Describe the uncertainty indicators associated with nautical charts.
B5.4 Navigation publications *(B)*	a) Sailing directions, b) Light and radio lists, c) Tides and current tables	Use content of nautical publications in a survey planning context.

Topic/Element	Content	Learning outcomes
	d) Notice to mariners	
B5.5 Compasses *(B)*	a) Earth magnetic field b) Magnetic compasses c) Gyros d) Compass error and corrections	Describe the capabilities, limitations and errors of magnetic and gyro compasses. Determine and apply corrections for magnetic and gyro compass error.
B5.6 Emergency procedures *(B)*	a) Fire extinguishers b) Life preservers and cold water survival suits, life rafts c) Distress signals and EPIRB d) Procedures for man-overboard, fire, and abandoning ship	Explain the importance of the emergency equipment and procedures.
B5.7 Safe working practice *(B)*	a) Water-tight doors and hatches b) Suspended loads c) Enclosed spaces d) Working aloft, with equipment over the side e) Work permitting f) Securing equipment for sea g) Cables and antenna installation h) Earthing of electrical equipment i) High voltage electrical safety j) Personal protective equipment	Describe procedures for maintaining a safe working environment. Draw a diagram to indicate safe cable routes for survey instruments. Describe methods for securing equipment for heavy weather.
B5.8 Rope and wires *(B)*	a) Types of wire and rope	Select and tie basic knots.

Topic/Element	Content	Learning outcomes
	b) Characteristics (stretch, floating, strength) of ropes. c) Basic knots	Select appropriate wire or rope.
B5.9 Towed and over the side instruments *(B)*	a) Rosette systems and instruments b) ROVs, AUVs, towed systems, catenary and layback c) A-frames, cable blocks, electro-mechanical wire, slip rings and optical cabling d) Moonpools e) Launch and recovery f) Station keeping and maneuvering	Deploy and recover oceanographic and hydrographic equipment
B5.10 Anchoring *(B)*	a) Shipboard ground tackle including anchor, chain, windlass, stoppers b) Small boat anchoring c) Multiple anchors	Describe ship and small boats anchoring and ground tackle. Explain how the final position of the vessel can be adjusted through the use of anchors.
B5.11 Instrument moorings *(B)*	a) Launch and recovery b) Anchors and acoustic releases c) Scope, wire, flotation, tension d) Weights	Prepare, deploy and recover seabed instruments.

1.6. B6: Meteorology

Topic/Element	Content	Learning outcomes
B6.1 Weather observations *(B)*	a) Vertical structure and the variability of the atmosphere	Define physical meteorological parameters Operate instruments and sensors used to register temperature, pressure,

Topic/Element	Content	Learning outcomes
	b) Temperature, humidity, dew-point, frost-point c) Atmospheric pressure, winds d) Clouds and precipitations	direction and intensity of wind. Record these parameters according to internationally accepted standards. Identify characteristics of weather by simple observation of the sea and the sky.
B6.2 Wind *(B)*	e) Rain, snow f) Visibility, advection fog and radiation fog g) Pressure systems h) Geostrophic winds, anabatic and katabatic winds i) Instruments and sensors used to register temperatures, pressure, direction and intensity of wind	Explain the relation between atmospheric pressure, temperature and wind. Describe wind circulation around pressure systems and the effect of friction.
B6.3 Weather forecasting *(B)*	a) Synoptic charts b) Weather forecast	Interpret a synoptic chart. Produce an operational short range forecast based on meteorological information, weather bulletins and facsimile charts

2. Essential subjects

2.1. E1: Underwater Acoustics

Topic/Element	Content	Learning outcomes
E1.1 Acoustic Theory		
E1.1a Generation of acoustic waves *(B)*	a) Plane and spherical waves in terms of wavelength, amplitude and frequency. b) Speed of sound in relation to water properties and profile in the water column.	Explain how transducer parameters impact upon beam characteristics.
E1.1b Propagation of acoustic waves *(I)*		Using appropriate units, describe acoustic wave behavior with reference to physical properties of the water column. Create a sound speed profiles from water column measurements and describe

Topic/Element	Content	Learning outcomes
	c) Acoustic units, intensities and sound levels d) Active Sonar Equation including sound source, causes of propagation loss in relation to water properties together with characteristics of the sea floor and targets, noise level and directivity e) Refraction and the path of sound rays through the water column. f) Transducer principles and beam characteristics g) System parameters including bandwidth, pulse length, pulse repetition rate, gain, detection threshold, range resolution and spatial resolution.	its effect on the acoustic ray path.
E1.1c Reflection, scattering and system performance *(B)*		Detail sources of noise and the impact of noise on operation of acoustic systems.
E1.1d Reception of acoustic waves *(B)*		Explain how a system is optimized in terms of environmental factors for measurement and target detection.
E1.2 Single Beam Systems & Side Scan Sonar		
E1.2a Single beam echo sounders *(I)*	a) Split beam and dual beam echo sounders b) Components of a single beam echo sounder. c) Operation of single beam echo sounders. d) Bottom detection principles. e) Full-echo-envelope returns f) Sub-bottom profiling systems. g) Validation & Calibration.	Set up, deploy and operate a single beam echo sounder. Select appropriate range, scale, frequency and pulse repetition rate for specific applications in relation to spatial resolution, bottom penetration and depth of water.
E1.2b Single beam echo sounder data recording. *(I)*		Interpret echo sounder returns through differentiation between return signals.
E1.2c Range uncertainty *(I)*		Detail and quantify components contributing to uncertainty in derived ranges.
E1.2d Side scan sonar *(I)*		Set up, deploy and operate side scan sonar. Interpret side scan sonar records considering target

Topic/Element	Content	Learning outcomes
	h) Principles, components, geometry and deployment of side scan sonar systems. i) Side scan sonar backscatter and sea floor reflection. j) Side scan images and sources of distortion. k) Combining sources of uncertainty.	characteristics, system configuration, potential sources of noise and distortion.
E1.3 Swath Systems		
E1.3a Beam characteristics *(B)*	a) Transducer elements and arrays. b) Beam forming and beam steering c) Principles and geometry of multi-beam and interferometric (phase measurement) sonar systems d) Amplitude and phase bottom detection e) Variations in beam spacing and footprint size f) Backscatter and seabed classification g) Hull and pole mounting of transducers considering platform motion. Integration of components including time stamping, attitude compensation, sensor offsets and networking.	Define characteristics of beams in relation to transducer settings. Compare phase and interferometric systems with multi-beam systems
E1.3b Backscatter and water column returns *(B)*		Describe characteristics of returns in the context of seabed type, angle of incidence and scatter from within the water column
E1.3c Bottom spatial coverage *(I)*		Determine sounding density and object detection capability as functions of system parameters
E1.3d Installation and configuration *(B)*		Describe suitable mounting structure and location for transducers given operational constraints
E1.3e Range and angle uncertainty *(I)*		Differentiate between error sources in phase and amplitude detection modes. Identify sources of range and angle uncertainty depending on acoustic parameter configuration
E1.3f Operation *(I)*		Set up, deploy and operate a swath sonar system. Identify problems or artefacts in on-line data due to inappropriate configuration

Topic/Element	Content	Learning outcomes
	h) Surface and water column sound speed monitoring i) Gain, power, pulse length j) Quality control procedures	or changing environmental parameters. Tune acoustic parameters for optimum performance. Apply quality control procedures to data acquisition and on-line processing

2.2. E2: Remote Sensing

Topic/Element	Content	Learning outcomes
E2.1 LiDAR		
E2.1a Airborne LiDAR systems *(B)*	a) Wavelength, water penetration and ground detection b) Scanning frequency and pattern in relation to power, coverage and spatial density. c) Influence of sea surface roughness, water column turbidity on the beam pattern and penetration. d) Sea bed optical characteristics and bottom detection. e) Secchi disc and Secchi depth f) Optical characteristics of coastal terrain. g) Influence of geometry and waveform on feature detection. h) Integration of components including time stamping, attitude compensation, sensor offsets and networking. i) Combined bathymetric and topographic LiDAR systems	Explain the principles, capabilities and limitations of topographic and bathymetric LiDAR. Describe the physical environment and operational situations in which bathymetric LiDAR surveys are complementary to echo sounder surveys
E2.1b Airborne LiDAR data products *(B)*		Extract high and low water lines from bathymetric and topographic LiDAR data sets. Use topographic and bathymetric LiDAR data to complement other spatial data.
E2.1c Terrestrial LiDAR *(B)*		Use terrestrial LiDAR data to complement other coastal spatial data.

Topic/Element	Content	Learning outcomes
E2.2 Remote Sensing		
E2.2a Remotely sensed bathymetry *(B)*	a) Multispectral imagery and water penetration in relation to wavelength b) Satellite Derived Bathymetry (SDB) c) Spatial resolution and accuracy available.	Demonstrate awareness of techniques and data sources in remotely sensed bathymetric data and the spatial parameters associated with such data.
E2.2b Shoreline delineation *(B)*	a) Multispectral imagery, reflectance in relation to wavelength and terrain characteristics. b) Geometrical properties of satellite images and aerial photographs	Describe geometrical properties of images and use them to create a shoreline map from images and aerial photographs.

2.3. E3: Water Levels and Flow

Topic/Element	Content	Learning outcomes
E3.1 Principles of Water Levels		
E3.1a Tidal fundamentals *(B)*	a) Tide generating forces, the equilibrium and real tides. b) Major harmonic constituents and different types of tide. c) Amphidromic points and co-tidal charts. d) Geomorphological influences on tidal characteristics	Explain tidal characteristics in terms of tide raising forces and local and regional morphological features.
E3.1b Tidal information *(B)*	a) Tide and current tables b) Tide prediction tools	Use tide tables and appropriate software to determine predicted water levels and tidal currents.
E3.1c Non-tidal water level variations *(B)*	a) Changes in water level caused by: atmospheric pressure, wind, seiches, ocean temperature and precipitation. b) Water level variations in estuaries, wetlands and rivers	Describe the effect of non-tidal influences on tidal water levels in the conduct of a hydrographic survey Describe sources of water level variations occurring in inland waters

Topic/Element	Content	Learning outcomes
	c) Water level variations occurring in inland lakes, rivers, reservoirs and canals	
E3.2 Water Level Measurement		
E3.2a Water level gauges *(I)*	a) Operating principles of various types of water level gauges including pressure (vented and unvented), GNSS buoys, float, radar, acoustic sensors and tide poles/boards/staffs. b) Installing water level gauges, establishment and levelling of associated survey marks c) Networks of water level gauges d) Reference levels such as MSL, chart datum, and mean high water. e) River and lake datums f) Uncertainties associated with measurement devices g) Uncertainties associated with duration of observations. h) Uncertainties associated with spatial separation of water level measurements.	Explain the principles of operation of different types of water level gauges. Install, level and calibrate a water level gauge.
E3.2b Tidal measurement *(I)*		Configure water level gauges for logging data, data communication, data download and for network operation with appropriate quality control measures.
E3.2c Water level datums *(B)*		Define various tidally based reference levels on the basis of tide time series and explain how these values are computed. Describe how vertical reference levels in rivers and lakes are defined, and determined in practice.
E3.2d Uncertainty in water level *(B)*		Relate uncertainty in water levels to uncertainties in measurement, duration and distance from water level gauge.
E3.3 Water Level Reduction		
E3.3a Water level reduction of soundings *(I)*	a) Vessel draft, squat b) Lever-arms and Position Reference Point offsets c) Vertical datums for sounding reduction d) Predicted tides versus measured tide reduction e) Co-tidal charts	Use tidal information, and vessel parameters to reduce soundings to a specified datum.
E3.3b Reduction of soundings using GNSS observations *(I)*		Configure and calibrate GNSS to reduce soundings to a specified survey datum.

Topic/Element	Content	Learning outcomes
	f) Reduction of survey data to a datum using GNSS observations g) Reduction of survey data using water level observations	
E3.4 Currents		
E3.4a Tidal streams and currents *(B)*	a) The relationship between currents and tides b) Rectilinear and rotary tidal streams c) Methods for measuring tidal streams and currents, including current meters, acoustic current profilers (ADCP) and drogues. d) Current surveys e) Surface current radar observation f) Portraying current data	Explain the forces behind currents and change in currents with tides.
E3.4b Current measurement and portrayal *(B)*		Describe techniques for current measurement and identify appropriate methods for acquiring and displaying current data.

2.4. E4: Positioning

Topic/Element	Content	Learning outcomes
E4.1 Geodesy		
E4.1a Introduction to Geodesy *(B)*	a) Shape of the Earth as a sphere, ellipsoid of revolution and the geoid; b) Definitions of astronomical terms and time. c) Geodetic computations on the ellipsoid. d) Local geodetic reference frames e) Vertical datums f) Terrestrial reference systems and reference frames.	Describe the shape of the Earth in terms of potential and ellipsoidal models
E4.1b Coordinate systems, frames and datums *(B)*		Describe modern geodetic reference systems and associated reference frames.
E4.1c Geodetic transformations and associated computations *(B)*		Describe horizontal and vertical datum transformation concepts
E4.1d Ellipsoidal computations *(B)*		Describe geometry of lines on the ellipsoid and perform forward and inverse computations on the ellipsoidal surface using available software.

Topic/Element	Content	Learning outcomes
	g) Modern geodetic datums WGS84, GRS80. h) Datums and datum transformation techniques	
E4.2 Principles of Cartography		
E4.2 Map projections *(B)*	a) Geometrical properties of map projections b) Cylindrical, conical projections including the UTM system and stereographic c) Analytical projection formulae and planimetric coordinates d) Distortions in distance and direction associated with different map projections	Describe the properties and distortions in different types of projections used in maps and charts. Explain the selection of projection type and apply appropriate projection formulae.
E4.3 Positioning Measurements, Methods and Techniques		
E4.3a Positioning fundamentals *(I)*	a) Principles of distance measurement and angle measurement b) Principles of 2D adjustment c) Sextant d) Total station e) Theodolite f) Electromagnetic positioning devices g) Intersection, Resection, Polar and Traverse h) Astronomic methods for determination of orientation.	Undertake control surveys, establish, mark and describe control stations, describe horizontal positioning procedures, apply appropriate methods and use corresponding instruments for positioning. Correct gyros using astronomic methods.
E4.3b Satellite positioning *(I)*		Explain the GNSS concept and principles. Define pseudo ranging and carrier phase based modes of satellite positioning Differentiate between base station and permanent networks, real-time and post-processing.
E4.3c Positioning systems *(I)*		Field test and use distance and angle measurement instruments. Apply field validation procedures

Topic/Element	Content	Learning outcomes
	i) Expansion of traditional geodetic networks j) Principle of GNSS positioning	Operate GNSS and DGNSS equipment, assess accuracy and precision, post-process GNSS data using appropriate software.
E4.3d Historical surveys *(B)*	k) GNSS services characteristics (single baseline, network, Precise Point Positioning)	Relate historical surveys to legacy positioning systems.
E4.3e Survey control *(I)*	l) Performance of code vs. carrier; differential vs. autonomous modes; multiple vs. single frequency; fixed vs. float ambiguity resolution m) Atmosphere (troposphere, ionosphere) effects on GNSS signals n) Control stations o) Logistical aspects of providing control	Establish, mark, and describe control stations, particularly hydrographic stations.
E4.4 Vertical Positioning		
E4.4a Height systems *(B)*	a) Height systems (dynamic, orthometric and normal)	Differentiate between gravity-related and ellipsoidal heights
E4.4b Elevation measurements and computation *(I)*	b) Leveling instruments c) Total stations d) Effects of curvature and refraction e) GNSS observations	Describe methods for determining elevation differences. Determine height using GNSS equipment. Compute elevations and leveling networks from observed leveling data. Use observation techniques for correction of curvature and refraction.
E4.5 Acoustic Positioning		
E4.5a Acoustic positioning concepts *(B)*	a) Long baseline b) Short baseline c) Ultra-short baseline	Describe the deployment, calibration, signal structure and performance of acoustic positioning devices. Describe the use of acoustic positioning

Topic/Element	Content	Learning outcomes
	d) Transponders e) Depth sensors f) Integration with INS and velocity sensors g) Use of acoustics for positioning towed vehicles, ROVs and AUVs	systems in offshore survey operations.
E4.5b Acoustic positioning systems *(B)*		Describe the principles of integrated subsea positioning systems and their application to remote survey platforms
E4.6 Inertial Navigation		
E4.6a Inertial Measurement Units *(B)*	a) Gyros and accelerometers b) IMU c) Procedures for INS static and dynamic alignment d) Use of IMU in heave estimation e) Aided Inertial navigation: a) ADCP/INS b) GNSS/INS c) USBL/Depth/INS	Describe principles and use of IMU's including north finding and heave estimation. Compare IMU heading measurements with magnetic and gyro compasses.
E4.6b Inertial Navigation Systems *(B)*		Distinguish IMUs and INS, and describe dynamic alignment of INS. Explain the concepts of aided inertial navigation system.
E4.7 Uncertainty in Positioning		
E4.7 Sources of uncertainty *(I)*	a) Static surveys: a) GNSS observations b) Total stations c) Leveling instruments d) Acoustic positioning b) Mobile surveys: a) GNSS equipment b) IMU/INS	Describe and explain the sources and magnitude of uncertainties associated with each positioning method and positioning system. Monitor, review and assess the performance of each positioning system to be used including repeatability, precision and accuracies of relative and absolute positions using appropriate statistical tools.

Topic/Element	Content	Learning outcomes
	c) Acoustic positioning c) Total propagated uncertainty	

2.5. E5: Hydrographic Practice

Topic/Element	Content	Learning outcomes
E5.1 Hydrographic Survey Projects		
E5.1a Hydrographic survey purposes *(I)*	a) IHO S-44 and other survey quality standards. b) Hydrographic instructions and tenders c) Types of surveys, such as: a) Nautical charting survey b) Boundary delimitation survey c) Ports, Harbor and waterways surveys d) Engineering works and dredging surveys e) Coastal engineering surveys f) Inland surveys g) Erosion and land-sea interface monitoring	Compare, interpret and apply hydrographic instructions and tenders associated with survey specifications.
E5.1b Hydrographic survey execution requirements *(I)*		Identify the different phases and terminology associated with types of survey operations.
E5.1c Hydrographic survey project organization *(B)*		Distinguish the roles and responsibilities of individuals within a survey team.

Topic/Element	Content	Learning outcomes
	h) Environmental impact assessment i) Deep sea and ROVs /AUVs surveys j) Seismic and geomagnetic surveys k) Pipeline route, pipeline installation and cable laying surveys	
E5.2 Hydrographic Survey Operations		
E5.2a Operational survey data transfer *(I)*	a) Remote water level measurement, b) Shore based stations in support of positioning systems c) Use of remote survey platforms and real time communication of data acquired. d) Data telemetry links including radio, satellite, telephonic and underwater communications. e) Compatibility between equipment and communications devices.	Describe data telemetry in support of on board survey data including applications and methods. Implement a data telemetry link between a survey infrastructure component and a survey system for real-time use.
E5.2b Survey systems *(I)*	a) Installation and calibration requirements for: a) Echo sounders	Explain the importance of the correct installation, calibration and determination of the attitude and position of each sensor.
E5.2c Calibration and corrections *(I)*		Setup, integrate and test survey system including sensors, acquisition system

Topic/Element	Content	Learning outcomes
	b) Swath systems c) Side scan sonar d) Surface and sub-surface positioning system e) IMU/INS b) Sound velocity probes and profilers c) Data acquisition and integration systems d) Bar check e) Boresight calibration for alignment bias f) Layback calculations	time-stamping strategy with appropriate physical offset determination. Explain the purposes and apply speed of sound measurements in acoustic systems.
E5.2d Line planning *(I)*	a) Planning for data acquisition including line spacing and sample locations in alignment with tasks to be performed on surveys and equipment to be used. b) Planning of survey operation considering currents, tides and survey speed. c) Track guidance and route following information systems.	Plan survey vessel survey lines as well as towed, remote vehicle and autonomous vehicle lines in space and time.
E5.2e Line keeping *(B)*		Explain the methods of maintaining a survey vessel or survey system on a planned survey line or route. Describe the effects on the survey quality due to the vessel motion (speed over the ground, angular velocity).
E5.2f Survey operations *(B)*	a) Survey parameters including: a) scale,	Describe the roles and the relationships of the following survey parameters: scale, positional accuracy, survey speed, line orientation, survey lines, interlines, cross lines, fix interval, data coverage.

Topic/Element	Content	Learning outcomes
E5.2g Quality control *(I)*	b) positional accuracy and precision, c) survey speed, d) line orientation, e) environmental and oceanographic parameters f) survey lines, interlines and cross lines, g) sounding density and spatial resolution h) overlap i) data coverage. b) Quality control of: a) Horizontal position b) Vertical position (heave, squat, water level) c) Coverage and overlap d) Swath system data e) Sound speed	Explain methods for quality control of survey data and the quality assurance of survey operations.
E5.3 Hydrographic Survey Documentation		
E5.3a Documentation *(I)*	a) Production of reports associated with the survey to include items such as:	Create and compare different documents associated with survey procedures in alignment with requirements using files, charts and reporting tools.

Topic/Element	Content	Learning outcomes
	a) Coverage including special investigation areas b) Features such as rocks, wrecks, obstructions, wellheads and pipelines (least depth, extent and position) c) Track charts d) Geodetic control on features such as shoreline and navigation aids	
	b) Metadata to include data types of data obtained together with associated quality measures such as positional, thematic and temporal uncertainty as well as lineage. c) Maintaining survey notes on event by event findings during data acquisition. d) Quality control procedures implemented and calibration reports produced e) Compliance with survey specifications and standards.	Describe the sources and means by which metadata files are created and populated.
E5.4 Legal Aspects		

Topic/Element	Content	Learning outcomes
E5.4a Liability of the hydrographic surveyor *(B)*	a) Nautical charts. b) Notice to mariners. c) Survey reports. d) Fundamentals of professional liability relating to surveying	Detail the role and responsibilities of the hydrographic surveyor as required under professional ethics, industry standards and national/international legislation/ conventions. Explain the potential liability of the hydrographic surveyor
E5.4b Delimitations *(B)*	a) Historical development of 1982 UNCLOS Baselines – normal (including closing lines); straight and archipelagic b) Base points c) Baselines d) Internal waters. e) Territorial seas. f) Contiguous zones. g) Exclusive Economic Zone h) Extended continental shelf. i) High seas	Describe the types of baselines under UNCLOS and how the territorial sea limit is projected from them, including the use of low tide elevations.

2.6. E6: Hydrographic Data Management

Topic/Element	Content	Learning outcomes
E6.1 Real-Time Data Acquisition and Control		
E6.1a Hydrographic Data acquisition *(I)*	a) Integration and logging of data from various sensors in accordance with survey specifications to include equipment such as: a) Echo sounder (SBES, MBES)	Configure the data collection and recording software for sensors and select sampling rates, gating and filtering settings. Describe the process of on-line data validation and selection.
E6.1b Real-time data monitoring *(I)*		Demonstrate that the data meets survey requirements through on-line monitoring of display and visualization tools. Use

Topic/Element	Content	Learning outcomes
	b) LiDAR c) Sound velocity profiler, surface velocity probe d) Side-scan sonar e) Surface positioning system f) IMU / INS g) Subsea positioning system (USBL) h) ROV / AUV / ASV b) Data acquisition system and software c) Time-tagging d) Data visualization	monitoring software to detect possible biases and errors in the data.
E6.1c Data transfer and storage *(I)*	a) Content of files in different formats used to record data in survey planning, data acquisition and products. b) Organization of survey databases c) Data storage and backup systems	Create the required data types that will be part of standard exchange formats. Configure systems for secure storage, transfer and backup of survey data
E6.2 Data Processing and Analysis		
E6.2a Spatial data cleaning *(I)*	a) Data cleaning techniques (manual and automated) b) Identification of outliers c) Identification of real features	Apply data cleaning techniques using appropriate software. Distinguish between noise, outliers & real features

Topic/Element	Content	Learning outcomes
E6.2b Spatial data quality control *(I)*	a) Total propagated uncertainty — horizontal b) Total propagated uncertainty — vertical c) Comparing crossing or adjacent data between survey lines d) Comparing overlapping data between survey platforms e) Identification of systematic errors	Assess the total propagated uncertainty of survey data relative to the survey specificationApply procedures used to assess, accept and reject data.
E6.2c Spatial data representation *(I)*	a) Data interpolation techniques b) Grids and TINs c) Contouring d) Volume computations	Apply spatial data processing methods to create digital terrain models or gridded surfaces and contouring. Apply estimation procedures to survey measurements and volume computations.
E6.3 Data Organization and Presentation		
E6.3a Databases *(B)*	a) Raster and vector data models and commonly used file types b) Spatial Data Infrastructures including GIS c) Databases to hold different types of feature and geographical information	Explain the concepts of raster and vector data models. Describe the concepts of Spatial Data Infrastructures (SDI). Use file types that support the exchange of hydrographic data to transfer data between acquisition, database and GIS environments.
E6.3b Marine GIS basics *(I)*	a) Features and feature types of point, line and polygon with marine examples. b) Marine and coastal data bases	Explain the concept and use of Geographical Information Systems (GIS) within the marine environment. Create a GIS project using marine spatial data. Merge and mash up data sets of different origin by

Topic/Element	Content	Learning outcomes
	c) Coordinate reference system d) Vertical datums e) Survey metadata f) Base maps and images	applying datum and projection transformations.
E6.3c Visualization and presentation *(I)*	a) Symbology b) Use of color schemes c) Shading and illumination d) Resolution e) Vertical scale / exaggeration	Configure elements of a viewing package to highlight features of interest within a hydrographic data set.
E6.3d Deliverables *(I)*	a) Products provided directly from source data such as sounding data files and metadata. b) Feature databases such as wrecks, rocks and obstructions c) Data required for sailing directions, light lists, port guides and notices to mariners. d) Data required for offshore hazards and anomalies survey e) Digital and paper products derived from source data for various survey types and usage such as GIS and CAD files and/or geo-referenced images. f) Reports on quality control, procedures, results and conclusions	Describe hydrographic deliverables and produce paper products as well as digital products in accordance with specifications and standards. Prepare a report on a hydrographic survey.

Topic/Element	Content	Learning outcomes
	detailing processes adopted within survey operations and data processing. g) Product standards including: a) IHO S-100 and product standards such as S-102. b) Standard Seabed Data Model (SSDM).	

2.7. E7: Environment

Topic/Element	Content	Learning outcomes
E7.1 Oceanography		
E7.1a Physical properties of sea water *(I)*	a) Units used in measuring and describing physical properties of sea water, normal ranges and relationships including: salinity, conductivity, temperature, pressure, density. b) Oceanographic sampling and methods for measuring common oceanographic parameters and profiles c) oceanographic sensors (e.g. for temperature, conductivity, and depth) and need for calibration	Use oceanographic sensors to measure physical properties of sea water and compute speed of sound using observed physical properties of sea water.
E7.1b Oceanographic measurements *(I)*		Set up, test and verify oceanographic survey sensors to meet specifications.
E7.1c Waves *(B)*	a) Wave parameters and elements involved in the wave growth process including fetch and bathymetry b) Breaking waves, long-shore drift and rip current processes.	Outline wave generation processes and discuss mitigation tactics against the impact of waves in planning survey operations.
E7.2 Marine Geology and Geophysics		

Topic/Element	Content	Learning outcomes
E7.2a Seabed characteristics *(B)*	a) Seabed samplers such as grabs, corers and dredges and basic sediment types. b) Types of seabed c) Processes involved in seabed dynamics	Explain the objectives of seabed sampling detailing sampling equipment and how samples are stored and analyzed.
E7.2b Magnetic surveys *(B)*	a) Magnetic fields and anomalies b) Objectives of magnetic surveys to detect pipelines, cables and ordnance. c) Magnetometers	Describe Earth's magnetic field and explain the use of magnetometers and the objectives of magnetic surveys.
E7.2c Seismic surveys *(B)*	a) Continuous reflection/refraction seismic profiling. b) Typical sound sources, receivers and recorders. c) High resolution seismic systems d) Sub-bottom profilers	Explain the objectives of seismic surveys and the equipment used to conduct such surveys.
E7.3 Environmental impact		
E7.3a Impact of surveys *(B)*	a) Permanent and temporary threshold shifts (hearing) for marine mammals. b) Use of physical techniques such as bar sweeps in environmentally sensitive areas. c) Respect for cultural traditions in relation to use of the environment d) Marine protected areas	Describe appropriate procedures and limitations for use of surveying equipment in compliance with environmental laws and marine protected area regulations.

3. CFFP: Comprehensive Final Field Project

Programmes must include a supervised and evaluated Comprehensive Final Field Project with a minimum aggregate period of **at least four weeks**; see "GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS".

The Comprehensive Final Field Project for Category “B” level shall comprise a comprehensive field survey incorporating different aspects of hydrography in a complex environment with varying sea-floor and oceanographic conditions.

Students should undertake:

— Survey specification and planning;

— Hydrographic and oceanographic measurements using a comprehensive suite of instruments;

— Data processing, quality control and quality assurance ;

— Preparation of different type of product deliverables and reports.

NOTE the Comprehensive Final Field Project does not include the practical exercises that form a part of the course modules syllabi and are designed to complement the theory.

